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Design and Implementation of A New Two-Way Opto-Electronic Probe for Optical Information Processing Components Analysis

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ABSTRACT

In this paper, a new two-way measurement method of optical signal processing elements is presented. The proposed method can decrease testing time and reduce human errors induced by disconnection in conventional one-way testing method. We can measure the scattering parameters of optical devices with fast two-way measurement when applying the new probes in conventional network analyzers. We demonstrated using our designed opto-electronic probes can measure the frequency responses of S_{21} and S_{12} of optical information processing component simultaneously. No reverse connections are needed for transfer functions measurement. In the future, this system can be applied to measure the characteristics of broadband optical signal processing elements for system applications. The theoretical model we built is very match to the experimental results.

Key words: Opto-electronic Probe , Optical signal processing , Measurement , Fiber optics, Optical filter

1. INTRODUCTION

High speed optical signal transmission above Gbps in fiber communications show promising results recently[1 ~ 8] . Using lightwave technology for measuring S parameters of optical signal processing components has becoming an important issue. The application of a microwave network analyzer tailored an opto-electronic probe for analyzing fiber-optic signal processing components has been reported [9]. But, the human errors induced by disconnections are introduced with using full two ports S parameter measurement with changing direction of element. The purpose of "through" calibration is to correct errors in transmission coefficients in both the forward and reverse direction for the measurement of device with many ports [10]. But no equipment can achieve a two-way "through" calibration for optical signal processing elements until now. The use of lightwave technology for measuring S parameters of optical component is becoming important. Development of an optical component 100Gbps laser diode were reported recently[11]. The microwave photonic component characteristics measurement is obviously urgent now. Some calibrations of prototype true time delay optical signal processing applications, such as optical beam-forming circuit networks, array antennas and matched filters applications, are reported [12].

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In *Optical Storage and Optical Information Processing*, Han-Ping D. Shieh, Tom D. Milster, Editors, Proceedings of SPIE Vol. 4081 (2000) • 0277-786X/00/$15.00

In this paper, we propose and demonstrate a new probe for applying in optical component network analyzer. A two-way fast measurement can be achieved by using the new method to reduce testing time and human errors.

2.SYSTEM STRUCTURE AND RESULTS

2.1 Description of the system

The schematic diagram of the new method of testing two-port optical signal elements is shown in Fig.1. We designed a new two-way optoelectronic probe including an electrical circulator, an optical circulator, an optical transmitter and an optical receiver as the dashline block shown in Fig.1 .The device under test (DUT) is inserted in the middle of the two probes. We use two designed probes to set up the optical component S parameters measurement testbed. In this paper, we use a fiber ring as a DUT. The parameters of the DUT are G (coupling coefficient) = 0.9 , L(length) =154 cm and ρ (intrinsic loss of coupler)= 0.85, as shown in Fig.2.

When the system function of the network analyzer operates at the S_{21} mode and S_{12} mode, the network analyzer can output electronic frequency sweeping signal to the optical transmitter, then through the optical circulator to the DUT. After the signal go through the DUT, the optical signal received by the second probe. The optical signal will be converted to the electrical signal by the optical receiver. Because of the electrical circulators and optical circulators in these two probes can provide two-way signal bypassing function, the measurement system we setup can provide a two-way fast S-parameter measurement. In the following section, we use this system to measure a single fiber resonator notch filter.

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2.2 Theory and Experimental Results

The theorretical model of a single fiber ring resonator notch filter used as the DUT shown in Fig.2 is derived in this subsection. The signal flow chart of the DUT is shown in Fig.3. We define the transfer function of the first path as $H_1(z)$ and the second path as $H_2(z)$.

Output O_F (z) of the feedback path can be written as

$$\boldsymbol{O}_F(\boldsymbol{Z}) = \boldsymbol{H}_F(z)\boldsymbol{I}_F = \frac{\boldsymbol{L}\boldsymbol{Z}^{-1}\boldsymbol{I}_F}{1-\boldsymbol{L}\boldsymbol{G}\boldsymbol{Z}^{-1}\rho} \tag{1}$$

where G is the coupling coefficient, ρ is the intrinsic loss of coupler, L is the loop transmittance of the fiber loop line.

The output O_1 of the first path can be described as

$$\boldsymbol{O}_1(\boldsymbol{Z}) = \boldsymbol{H}_1(z)\boldsymbol{I} = \boldsymbol{G}\rho\boldsymbol{I} \tag{2}$$

The output O_2 (z) at the second path output is

$$\boldsymbol{O}_2(\boldsymbol{Z}) = \boldsymbol{H}_2(z)\boldsymbol{I}_2 = \left(1-\boldsymbol{G}\rho\right)^2 \boldsymbol{H}_F(\boldsymbol{Z})\boldsymbol{I}_2 = \frac{(1-\boldsymbol{G}\rho)^2\boldsymbol{L}\boldsymbol{Z}^{-1}\boldsymbol{I}_2}{1-\boldsymbol{L}\boldsymbol{G}\boldsymbol{Z}^{-1}\rho} \tag{3}$$

Combining the above three equations, we find the transfer function can be represented as

$$H(Z) = \frac{O}{I} = G\rho + \frac{(1-G\rho)^2 LZ^{-1}}{1-LGZ^{-1}\rho} \qquad (4)$$

From the above derived theoretical model of the DUT, we simulate the frequency responses of S_{21} and S_{12}. The simulation results of S_{21} and S_{12} are shown in Fig.4 and Fig.5, respectively. The measured results are shown in Fig.6 and Fig.7, respectively. Using the experimental setup shown in Fig.1, we can measure the frequency responses of S_{21} and S_{12}. Comparing the numerical and experimental results, we find these two results have good coincidence. This results shows our designed two-way opto-electric probe is very helpful for measuring the optical fiber information components.

3. CONCLUSION

In this paper, we made and design a new two-way optoelectronic probe for application in S parameters measurement of optical information processing components. Measuring a fiber ring notch filter as a DUT, we find the numerical results and the experimental results matched very well. Therefore, this two-way optoelectronic probe can be studied in the future for microwave-photonic information processing devices measurement.

ACKNOWLEDGMENT

This work was supported in part by National Science Council of Republic of China under contract no. NSC 89-2215-E-155-002.

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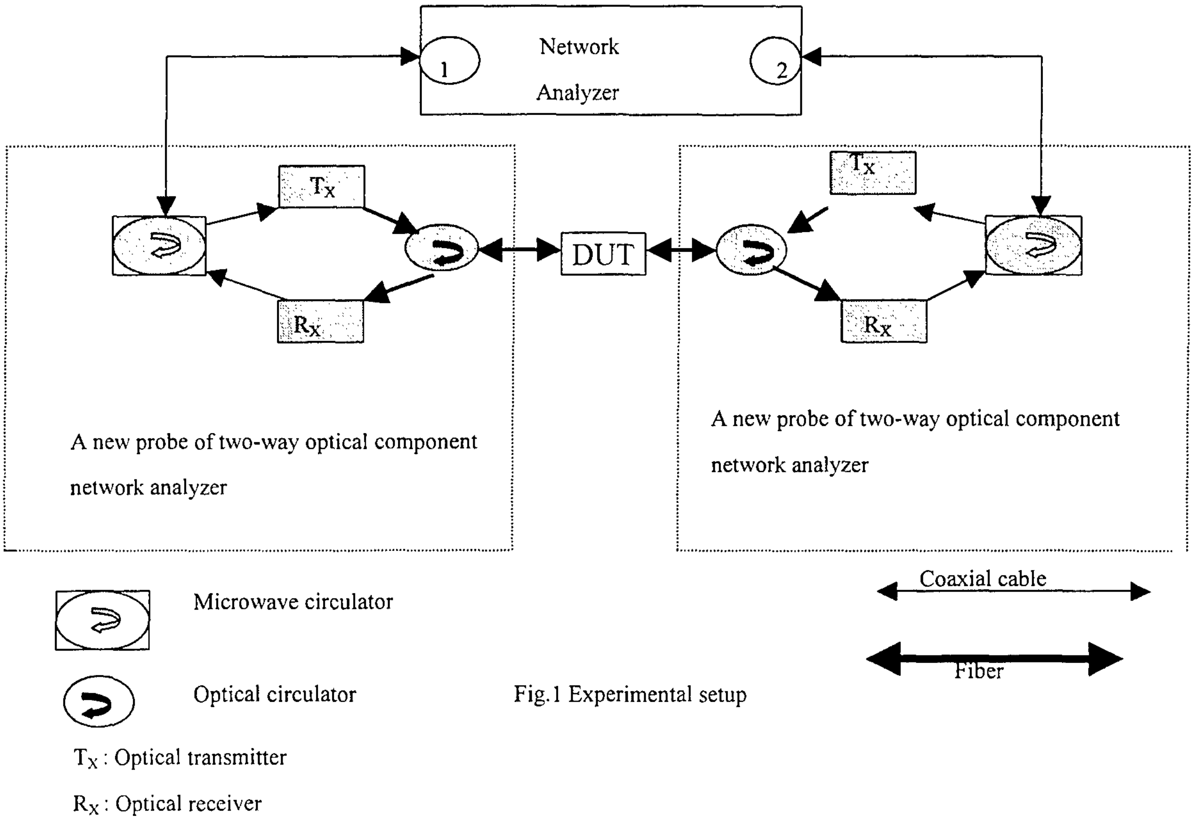


Fig.1 Experimental setup

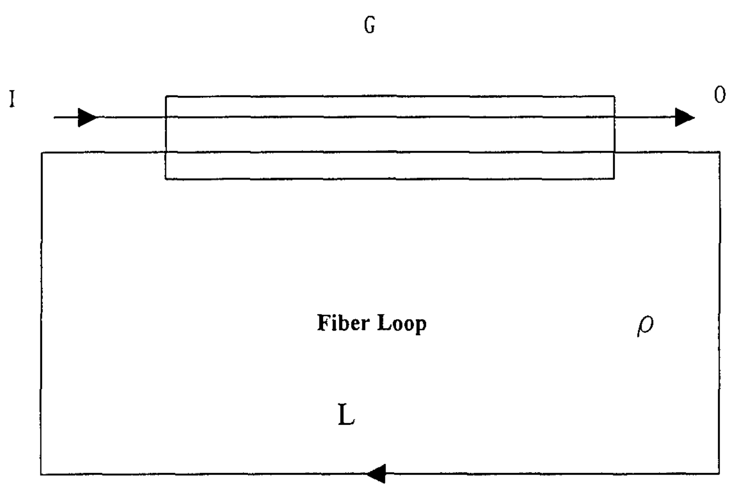


Fig.2 Schematic diagram of an SFRRF

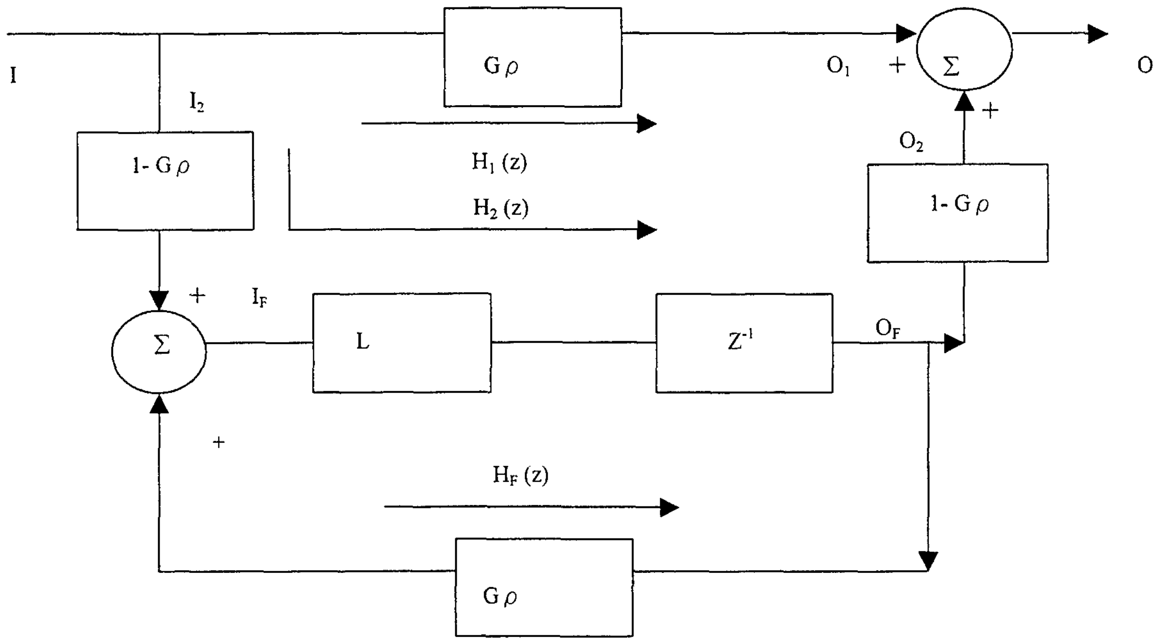


Fig.3 The singal flow chart of the fiber ring resonator notch filter as a DUT

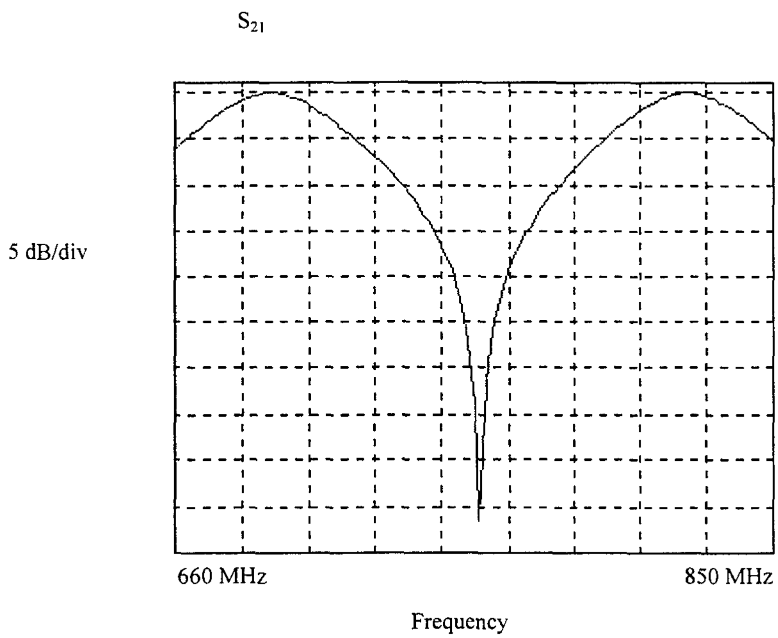
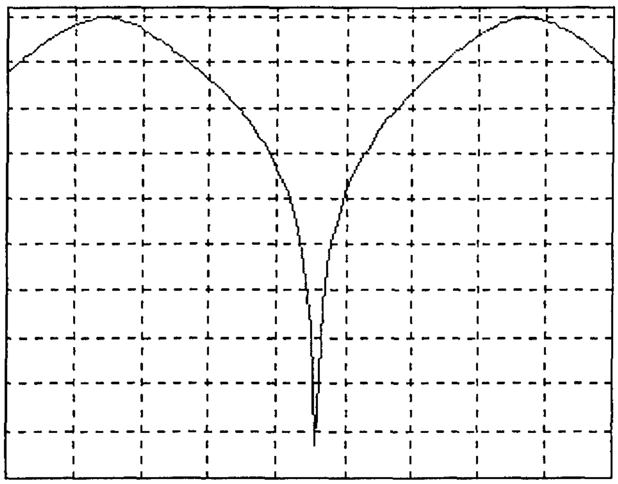


Fig.4 Simulated frequency response of S_{21} of the DUT

S_{12}

5dB/dib



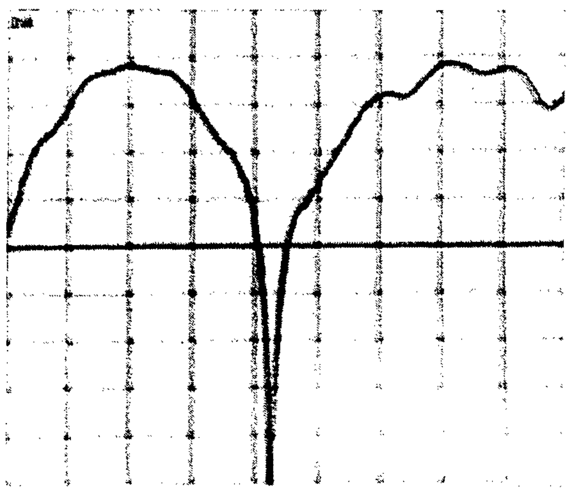
660 MHz   850 MHz

Frequency

Fig.5 Simulated frequency response of S_{12} of the DUT

S_{21}

5 dB/div



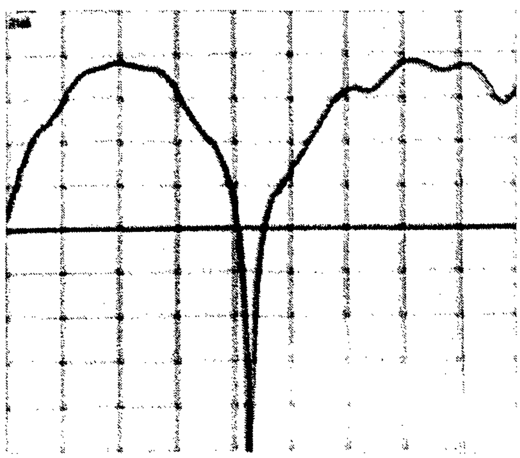
660 MHz   850 MHz

Frequency

Fig.6 Measured frequency response of S_{21} of the DUT

S_{12}

5 dB/div



600 MHz 850 MHz

Frequency

Fig.7 Measured frequency response of S_{12} of the DUT